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PROJECT VANGUARD REPORT NO. 11

PROGRESS THROUGH NOVEMBER 15, 1956

[UNCLASSIFIED TITLE]

Project Vanguard Staff

December 3, 1956

NAVAL RESEARCH LABORATORY
Washington, D.C.

SECURITY

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PREVIOUS PROJECT VANGUARD REPORTS

Project Vanguard Report No. 1, "Plans, Procedures, and Progress" by the Project Vanguard Staff, NRL Report 4700 (Secret), January 13, 1956

Project Vanguard Report No. 2, "Report of Progress" by the Project Vanguard Staff, NRL Report 4717 (Confidential), March 7, 1956

Project Vanguard Report No. 3, "Progress through March 15, 1956" by the Project Vanguard Staff, NRL Report 4728 (Confidential), March 29, 1956

Project Vanguard Report No. 4, "Progress through April 15, 1956" by the Project Vanguard Staff, NRL Report 4748 (Confidential), May 3, 1956

Project Vanguard Report No. 5, "Progress through May 15, 1956" by the Project Vanguard Staff, NRL Report 4767 (Confidential), June 2, 1956

Project Vanguard Report No. 6, "Progress through June 15, 1956" by the Project Vanguard Staff, NRL Report 4800 (Confidential), June 28, 1956

Project Vanguard Report No. 7, "Progress through July 15, 1956" by the Project Vanguard Staff, NRL Report 4815 (Confidential), July 27, 1956

Project Vanguard Report No. 8, "Progress through August 15, 1956" by the Project Vanguard Staff, NRL Report 4832 (Confidential), September 5, 1956

Project Vanguard Report No. 9, "Progress through September 15, 1956" by the Project Vanguard Staff, NRL Report 4850 (Confidential), October 4, 1956

Project Vanguard Report No. 10, "Progress through October 15, 1956" by the Project Vanguard Staff, NRL Report 4860 (Confidential), November 4, 1956

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PREFACE

This report is intended as a general summary of the progress on Project Vanguard during the indicated period. Hence, minor phases of the work are not discussed to a great extent, and technical detail is kept at a minimum. It is hoped that the information here presented will be of assistance to administrative and liaison personnel in coordinating and planning their activities, and as a guide to the current status of the project. Material of a more technical nature will be published from time to time in separate reports which will be announced in subsequent monthly progress reports.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem A0?-90

Manuscript submitted November 30, 1956

PROJECT VANGUARD REPORT NO; 11
Progress Through November 15, 1956

COORDINATION WITH OTHER SERVICES

ARMY

The Army has been requested by the Chief of Naval Research to delete the requirement for a prime Minitrack station in Panama. This reduces the number of Army-operated stations to six (see The Minitrack System).

The Army program for establishment of their six prime Minitrack stations is essentially on schedule. At a design review conference on 23 October, designs were approved by NRL and some slight changes incorporated in the plans. No material delay in the program is expected because of these late changes. The following key actions have also occurred.

1. Construction funds have been allocated and directives issued.
2. Station operating personnel have been selected and will be reported to the Adjutant General for assignment.
3. Arrangements for the training program at the NRL Blossom Point station are underway.
4. Bills of materials have been prepared and major items of communication equipment reserved for each site.
5. Preliminary engineering of the communications system is complete.

In connection with the SCEL program involving solar cells for satellite use, an experimental solar power system has been constructed for rocket tests and is now undergoing preliminary tests. Cycle-life data are being established on various electrochemical storage systems. Construction of a prototype system for an Aerobee rocket flight was initiated during the first week of November.

The SCEL have offered the use of their vibration test facilities to Vanguard and are also providing information and some special frequency control crystals for the Minitrack transmitters.

The work by BRL on T-11 DOVAP transponders and crystal-controlled receivers for Vanguard is completed, and all deliveries have been made. The ABMA is furnishing two special DOVAP transponders, and has maintained technical liaison concerning the use of flares and on solid-propellant rocket performance and ignition. Acceleration tests (see The Satellite) on Vanguard satellites have been made with a centrifuge at the DOFL. Vanguard is using ERDL facilities in the application of silicon monoxide coatings to the satellite.

AIR FORCE

The status of the Vanguard facilities at AFMTC is as follows:

The temporary air conditioner has been put into operation in the electronic instrumentation room of the Vanguard blockhouse, but is somewhat erratic and noisy. One window

has been installed, and the installation of the two remaining "horizon-seeing" windows is expected in time for the first static firing of TV-0. The "upward-seeing" windows will not be be required for the static firing.

The launch stand structure proved to be in a sufficient state of readiness for the erection of TV-0. All major power and instrumentation wiring, and hydraulic and pneumatic lines have been installed. Special temporary working stands have been placed around the base of the erected vehicle to lend access to the powerplant bay, the peroxide tank quadrant, and the controls quadrant. The electrical and lighting systems have proved satisfactory for nighttime operations.

Concreting of the sloping sides of the flume area is presently underway and completion is expected several days before the first static firing. The temporary hydrogen-peroxide passivation pad was completed in the AFMTC propellant storage area in time for the TV-0 passivation operations.

A stabilized and tarred roadway is now complete to the blockhouse area, and stabilization is well underway in other areas. Permanent concrete will be poured on two days notice after the first firing.

THE LAUNCHING VEHICLE

The TV-0 missile was transported to the launching area and erected on 13 November; the gantry was moved into position and the working platforms were closed around the vehicle. The nose cone and its instrumentation were moved to the upper platform, where preliminary mechanical alignment and electrical checks were completed. The main and forward controls cans were reinstalled, and the vertical and roll gyros were electrically connected and functionally checked with the energized control system. Qualitative functional checks of the system indicate no major discrepancies. The following portions of the pre-static-firing functional checks have been completed as of 15 November: (1) electrical power adjustments, and (2) calibration of the gimbal thrust chamber and roll-tab panel deflection meters.

The launching of this vehicle is now scheduled for the early part of December.

CONFIGURATION AND DESIGN

Transonic windtunnel tests at WADC,* covering the speed range from Mach 0.8 to Mach 1.2 on a 7-percent scale force model and a 4.5-percent scale pressure model of the launching vehicle, were completed on 2 November 1956. The resulting data were analyzed in rough form and an acceptable correlation between the force and pressure data was obtained. The final reduction of force coefficients is in process at WADC and delivery is expected by 12 November. Owing to their urgent need for pressure distribution plots, the Glenn L. Martin Company (GLM) is reducing all pressure data.

The Martin Company is preparing, in booklet form, a set of working and installation diagrams for electrical systems in TV-3 and subsequent vehicles. These diagrams are essential for manufacturing, but are difficult to use and inadequate for checking design and obtaining an overall view of the simultaneous and sequential operations that must be effected during launch-pad static firings and in an actual flight firing. To aid in checking circuit designs and in visualizing the integrated operations of all systems both in static and flight firing, an electrical schematic diagram showing the essential operation and their sequence is desirable. A preliminary diagram has been prepared showing the sequence of operations and the components involved in a flight firing, and work has been started on a schematic diagram of the electrical system.

The primary source of ac supply on TV-3 and subsequent vehicles is to be a 400-cps rotary inverter driven by the vehicle 28-volt dc supply. Qualification testing and modification of various units from different manufacturers has been started; the modification consists essentially of removing the voltage regulator and speed-control.

PROPULSION

First Stage

In the last report** it was stated that the specific impulses obtained in the first two test firings of production first-stage engine P-1 were found to be low. It was hoped that a second calibration of the test-pit instruments would improve the data. Since that time the

*P.V.R. No. 9, p. 3
**P.V.R. No. 10, p. 5

new calibration has substantiated the original calibration and has not improved the performance data. Fuel leakage at the injector-to-chamber body seal is now blamed for the low performance; therefore all subsequent motors will employ a copper seal between the injector and chamber to eliminate this condition.

The second production engine (P-2) has been acceptance tested. Following three calibration runs of 50 seconds duration, a full-duration run was made, and inspection after shutdown disclosed chamber scoring. The motor was disassembled and one fuel passage was found to be clogged with machining chips; this was blamed as the cause of a local hot spot which scored the wall. The defect in the chamber wall was weld-filled and ground smooth. This run was forfeited because of the work done on the injector, and two more full-duration runs were then made. Complete data are not available at this time but preliminary information indicates that performance for these two runs was within specifications, with specific impulses of 252.1 and 252.5 seconds respectively. No chamber scoring was evident after the completed test series. The P-2 engine package was inspected and removed from the stand and the third production engine (P-3) was installed. The P-2 engine is currently being held at the Malta test station for acceptance, which will be given when a satisfactory resolution of deviations from the specification has been accomplished.

Calibration runs have been completed on P-3 and one acceptance firing has been made. A failure of a fuel-pump gear was observed, and this component will be replaced; the history of the pump indicates no previous premature failure, but the gear will be analyzed to determine the reason for failure. A cursory review of raw data has shown that the mixture ratio was not within specifications in this firing. The run will be forfeited and repeated if the final review of the data confirms the preliminary review.

The fourth production engine is ready for testing. A prequalification engine (PQ-1) is also ready for testing and should be fired upon acceptance of P-3. The PQ-1 engine testing schedule will be adjusted so as not to interfere with the acceptance testing of production units.

During this report period GE continued its static tests on various seals and began dynamic tests with mixtures of 20-percent fluorine and oxygen. These flow tests were satisfactory: the materials which stood up in the static tests survived the flow tests. At the end of this report period GE set up a seal testing fixture utilizing the X-405 engine turbine pump-seal configuration. GE is prepared to substitute various materials for these seals including the material "Kentanium" which has been used successfully by the North American Aviation Corporation.

The NACA, Lewis Flight Propulsion Laboratory, has received most of the propellants needed for their phase of the oxidizer improvement program* and began firing the scaled-down X-405 5000-lb-thrust chambers which had been obtained from GE. These motors suffered burnouts after about 10 seconds, with oxygen alone as the oxidizer. This was shown to be caused by improper coolant passage design, which is presently being corrected. GE is effecting a very close collaboration with the NACA.

Second Stage

During this report period the Aerojet-General Corporation continued to fire its aluminum "spaghetti" thrust chambers, using the 72-pair impinging jet injector. This

*P.V.R. No. 10, p. 6

injector has been chosen as the standard item. It yields a characteristic exhaust velocity (c*) of about 4980 fps. This performance meets minimum specifications, and a c* of over 5000 fps would be more desirable in order to allow some leeway for small variations of mixture ratio or chamber pressure. Aerojet has ceased work on the 120-pair impinging jet and non-impinging showerhead injectors. The non-impinging injector is expected to have a characteristic exhaust velocity of about 5400 fps, and Aerojet is prepared to fire this injector in a Vanguard prototype chamber. This firing would demonstrate the approximate performance and heat flux values obtainable in the Vanguard chamber.

Thrust chamber fabrication has proceeded satisfactorily, and the first three deliverable prototype chambers have been completed and readied for injector installation. The thrust chambers show no evidence of burnout or wear after several full-duration firings, and the injectors show no evidence of scum or carbon deposits. Early during this report period severe vibrations were noted visually on the expansion nozzle. However, by strengthening the thrust-chamber support and by welding a small peripheral structural member onto the expanded part of the nozzle, these vibrations have been reduced and are no longer visually evident. Some vibration near the injector head also had been noticed but this has been resolved by properly mounting the chamber on the test stand. It is not yet apparent whether vibrations will occur when the chamber is mounted on the monoball joint on the lightweight tankage. Aerojet believes that the hydraulic actuators will damp out any severe vibrations.

Aerojet made two firings with red fuming nitric acid (RFNA) in place of the regular oxidizer, white fuming nitric acid (WFNA), and obtained a specific impulse slightly below that obtained with WFNA. This result is believed to have been due to a slightly off-mixture ratio and the rather high water content (slightly over 2 percent) of the RFNA. The RFNA was able to absorb sufficient heat from the chamber walls to prevent burn-through, as was expected.

The test facilities at Aerojet's Azusa plant have been completed and are in full operation. The Sacramento facility is almost ready for full-scale firings. Plans are underway at Sacramento for incorporating the lightweight propellant tankage assembly into the vertical test stand for full-duration prototype chamber firings. Several firings have been conducted at Azusa to investigate the problems of oxidizer run-out and outage, and the use of an oxidizer probe for determining the end of oxidizer flow before the cessation of chamber pressure. The oxidizer probe worked well and was able to shut down the system without delay. The amount of oxidizer left in the system had a constant value of about 30 cubic inches in 5 tests.

The first deliverable prototype main propellant valves have been completed and readied for prequalification and acceptance tests. The valves have stood up well to the usual cycling and response-time tests. The oxidizer burst diaphragms have also been tested and have burst within specified pressure tolerances. Several prototype and dummy tanks have been proof-tested and at least one lightweight deliverable tank assembly should be tested at Sacramento and readied for shipment about the end of November. Aerojet has two tank assemblies which have satisfactorily passed hydrostatic tests, one of its own construction and one from a subcontractor. Work on the proposed 17-7 PH (Armco) steel tank* has ceased.

* P.V.R. No. 5, p. 5

Third Stage

Allegany Ballistics Laboratory

The Allegany Ballistics Laboratory (ABL) has continued testing in order to solve the insulation problem at the slotted sections of the propellant.* The tests indicate that a silica-rubber insulator will not be adequate to retard severe heating during the firing duration. It is now proposed to partially fill in the slotted sections with about a half inch of cellulose acetate impregnated with nitroglycerine to obtain a very slow-burning material. This will curtail heating directly adjacent to the insulator for 15 seconds. A heat-resistant phenolic insulator will also be tried instead of the silica-loaded rubber liner. A firing was made with an uninsulated steel expansion cone 0.060-inch thick for evaluation. The cone burned out during firing, as anticipated.

Further heavy-walled steel chambers utilizing the proposed vacuum type igniter and delay squibs have been tested by ABL with success. Since the altitude vacuum chamber is now completed, further testing on ignition will be done with this equipment. A vacuum of 2 mm of mercury is anticipated.

The problems of supply of steel cases and carbon as well as the fabrication of the altitude expansion cone have been resolved. Evaluation testing of the fiberglass expansion cone and the steel cone coated internally with "Thermoclad" should be accomplished in November.

A dynamic balancing machine for the third-stage rockets has been promised by November 19; this item will be in operation near the end of November. The mechanical alignment fixture has been completed and is being installed.

Because of problems associated with development of the insulator and the requirements to be incorporated in the prequalification testing, ABL's prequalification tests will begin November 20 and should be completed five weeks later. ABL has been requested to perform five statistical evaluation firings with sea-level expansion nozzles, as a part of the prequalification testing. The vacuum specific impulse obtained by ABL is still estimated to be 250 seconds, with a total weight of 433 pounds.

Grand Central Rocket Company

The Grand Central Rocket Company (GCR) has completed evaluation of the two propellants, GCR 201C and GCR 207, and has indicated that GCR 207 would require additional study before incorporation in the Vanguard third-stage program. The Company has been directed to use GCR 201C, which has slightly lower performance but shows better reliability and environmental characteristics. Various tests have indicated that the propellant cracking problem is resolved. The vacuum specific impulse obtained by GCR is still estimated to be 245 seconds, with a total weight of 433 pounds.

Tests of the igniter in a small vacuum chamber will be made before the prequalification program begins. Satisfactory sea-level ignition has been obtained with an ignition delay of 1 to 1.5 seconds.

A discrepancy has been observed between the measured chamber pressure and the design pressure. Investigations indicate a possible transient variation in the nozzle throat

*P.V.R. No. 10, p. 8

diameter of about 0.035 inch during firing. It is presently planned to rely more on the static thrust measurement than on the pressure reading. A test was performed using a 3-inch extension on the sea-level nozzle to evaluate heating of the thin expansion case. The high heat flux eroded the nozzle, and thus indicated that a slightly thicker layer of "Rockide A" (Al_2O_3) insulation would be required for increased durability. Altitude expansion nozzles of the desired shape and thickness are expected to be available for prequalification tests. Acceleration tests of 2 g normal to the rocket and 7 g longitudinally applied at the aft end are to be made on November 21.

Because of the developmental problems of propellant cracking, ignition, and instrumentation, GCR's prequalification test program was delayed. The present schedule shows prequalification preparation and testing beginning November 20 and being completed 4 weeks later. GCR has been requested to perform five statistical evaluation firings with sea-level expansion nozzles, as a part of the prequalification testing.

FLIGHT CONTROL

Guidance

Reference System

Minneapolis-Honeywell has determined that an increased heater rating and a cooling-air bypass has met the prelaunch and flight requirements for gyro temperature control. Qualification tests have been initiated on a unit which differs from the production item in that the heaters are being run at overvoltage. Later substitution of 28-volt heaters with increased capacity is considered acceptable. As reported,* the selection of matched shockmounts permits the gyro drift requirements in the presence of the specified vibration environment to be met. A shipment of 80 shockmounts has been received and Minneapolis-Honeywell is proceeding to select matched sets.

Attitude Control

The Vickers qualification and acceptance specifications for the autopilot have been approved. A ramp input signal was specified to assure evaluation of the dynamic response of the jet system controls (autopilot, relays, and solenoid valves). The dynamic response of the jet amplifiers to the ramp input was not completely satisfactory and it was found that the preamplifier was saturating. Reduction of the interstage coupling allowed operation of the preamplifier over a linear current range which met the specified performance for the relay systems.

The lag circuit** which had been incorporated to overcome the instability evidenced in dynamic mockup tests of the breadboard magnetic amplifier has been removed and REAC studies with the dynamic mockup are being rerun to determine system performance with the modified preamplifier. A vehicle structural transfer function has been obtained from a linear approximation which neglects backlash and the spring constant of the vehicle structure at the point of actuator attachment. The resiliency is linearized — a procedure which is valid for small deflections. Hand computations indicate that the specified autopilot is inadequate for correcting instability due to feedback with this structural transfer function.

*P.V.R. No. 10, p. 9

**P.V.R. No. 9, p. 7, and No. 10, p. 10

The resonances were determined: the higher frequency lies between 50 and 120 radians per second and can be eliminated by a low-pass filter with an attenuation of 10:1. The lower frequency lies within the control region at 18 to 20 radians per second. A phase lead of approximately 30 degrees is required to stabilize the system. Investigation in this area is being continued in a REAC analysis.

The first-stage dynamic mockup has failed at the point of actuator attachment to the engine. Information has been given GE concerning the estimated dynamic test loading and test run durations in order that the structural design of the production units may be checked. A similar failure of the Aerojet second-stage dynamic mockup occurred at the point of actuator attachment to the fuel tankage.

In conjunction with present studies to determine the maximum wind profile to which the vehicle may be subjected before experiencing loss of control or structural failure, a REAC study is in process for determining whether the correcting moment will be sufficient when the first-stage engine deflection is limited to various fixed values. The wind velocity needed to produce the pitching moment at any time can be computed by using the more reliable aerodynamic coefficient data from the recently completed transonic wind tunnel tests. The vehicle dynamic responses to this moment at different times during the first-stage flight are also being determined. Structural limitations place a limit of 4.5 degrees on first-stage engine deflections. In the presence of specified wind profile and gusts an excursion of 2.8 degrees is required. The limit of 4.5 degrees is not exceeded if deflections in pitch and yaw are restricted to 3.2 degrees. The hydraulic actuators are being constructed with piston body length proportioned to obtain this angular deflection limit.

The status of the study to determine the maximum allowable wind profile is as follows:

1. The steady-state relationship between angle of attack and engine deflection has been obtained as a function of flight time. This has been put in the form of a nomogram.

2. Load diagrams are being constructed of limiting angle of attack and limiting engine deflection as a function of vehicle station.

3. A plot of normal (to the vehicle longitudinal axis) wind velocity corresponding to the obtained limiting angle of attack is being constructed.

4. The lateral velocity of the vehicle is being computed and added to the normal wind profile.

5. The normal wind velocity is being resolved to the horizontal to obtain the maximum wind profile which the vehicle can safely tolerate from the standpoint of structural limitation.

Flight Program and Staging

The integrating-accelerometer time computer will be flown in TV-3; however, third-stage spinup and ignition for this vehicle will be initiated at a fixed time after second-stage burnout. This requirement is imposed by range limitations of the nose-cone telemetry. Components will be installed in TV-3 to provide ground-based command for third-stage spinup.

Because of difficulty in the procuring a subcontractor for the phenolic laminated "peel-away" nose cone, GLM is fabricating an aluminum "peel-away" cone for explosive-bolt separation tests on 19 November.

The Atlantic Research Corporation (ARC) has completed prequalification tests on the spin and retro rockets. Qualification testing has been held up because cases have not been delivered; a new order has been placed with the Ballauf Manufacturing Company of Washington, D. C. (The present program calls for completion of the qualification phase by 7 December.) Testing for rain, salt, spray, humidity, and vibration will be conducted by the U. S. Testing Company, Hoboken, New Jersey during the first week of December.

Nine vacuum firings of these rockets have been conducted with no apparent malfunction. These tests have been run with a back-pressure between 2 and 100 microns of mercury, the average being about 20 microns. Present schedules call for shipment of eight motors to AFMTC on 14 December to be employed with TV-1.

Work is continuing at ARC on the insulating cover for the retro rockets to protect them from aerodynamic heating during the vehicle ascent. The cones are being fabricated from an asbestos-phenolic laminate (Raybestos-Manhattan 9526-D2) by Bassen Industries, Bronx, New York.

Tests on ordnance items for the Vanguard vehicle are being conducted by GLM. A structure has been completed to simulate and check out the sequencing of the spinup and retro separation of the third stage, and a full-scale structure is being made to test explosive-bolt separation of the first and second stages. Testing is presently scheduled for 1 February 1957.

Aerojet-General is testing the spin and retro rockets in their altitude vacuum chamber for ignition reliability. The vacuum is 10^{-6} mm of mercury. Aerojet is also performing tests on Primacord at low temperature (-300^{0} F) to simulate the destruct system on the lox tanks. A vacuum test of Primacord also is planned.

THE SATELLITE

CONFIGURATION AND DESIGN

20-inch Satellite

The internal package for the 20-inch satellite has been redesigned and aluminum models of the new design have been fabricated. The nominal dimensions of the new design are: inside diameter 5-1/2 inches, length 8-3/4 inches. This package will contain a total of seven electronic instrumentation modules, of which five will be 3/4 inch thick, one 1-5/16 inches thick, and one 2-1/2 inches thick.

At present it appears that heat switches will not be necessary in the 20-inch satellites. (See Environmental Tests).

The revised weight breakdown given in Table 1, reflecting the above changes and based upon magnesium as the structural material, should be compared with that given in the last Progress Report;* however, some rearrangement of the list will be apparent.

The fabrication of the 20-inch satellites in magnesium is approximately one month behind schedule, but it is not expected that this situation will result in a delay in the overall program.

6.44-inch Satellite

Two additional magnesium 6.44-inch satellite structures have been received, making a total of four to date. Two have been used in destructive tests, and the other two have been coated with silicon monoxide and are being used in thermal evaluation tests. The acceptance tests have been completed on these satellites and the contractor has been instructed to proceed with fabrication of the remaining units. The failures which occurred during these tests are listed below:

Vibration:

1. Rivets tore through the skin of one unit in the horizontal plane at the separation attachment during vibration at 45 cps and 20 g (Fig. 1).
2. Kel-F parts failed during horizontal vibration of two units at approximately 80 cps and 20 g (Fig. 2). The metal parts were not severely damaged, and both units were rebuilt. Some radii of the Kel-F parts were increased to reduce stress concentration points.
3. Kel-F parts failed during vertical vibration of one unit at approximately 85 cps and 25 g. The unit is being rebuilt.

*P.V.R. No. 10, p.14

TABLE 1
Breakdown of Current Estimated Weights
for the 20-inch Satellite

Component	Current Weight (lb)
MINITRACK SYSTEM	
Antennas	0.62
Batteries	6.78
Electronics	0.50
Plastic Foam	0.40
Total	8.30
LYMAN-ALPHA EXPERIMENT	
Electronics and Detectors	0.44
Batteries	0.25
Wiring and Plastic Foam	0.08
Skin Attachments	0.13
Total	0.90
TELEMETERING SYSTEM	
Coding System	0.19
Orbital Peak Memory Unit	0.19
Plastic Foam	0.25
Interconnecting Leads	0.19
Batteries	0.40
Total	1.22
ENVIRONMENTAL EXPERIMENTS	
Pressure Zones	2.10
Pressure Gage and Connections	0.21
Erosion Test Device	0.10
Meteor Counter and Amplifier	0.31
Four Microphones	0.25
Total	2.97
SEPARATION MECHANISM	0.94
DYNAMIC BALANCING	0.20
STRUCTURE	
Internal Frame	1.10
Internal Package and Supports	1.26
Shell	2.45
Total	4.81
MISCELLANEOUS	1.00
COMPLETE SATELLITE	20.34

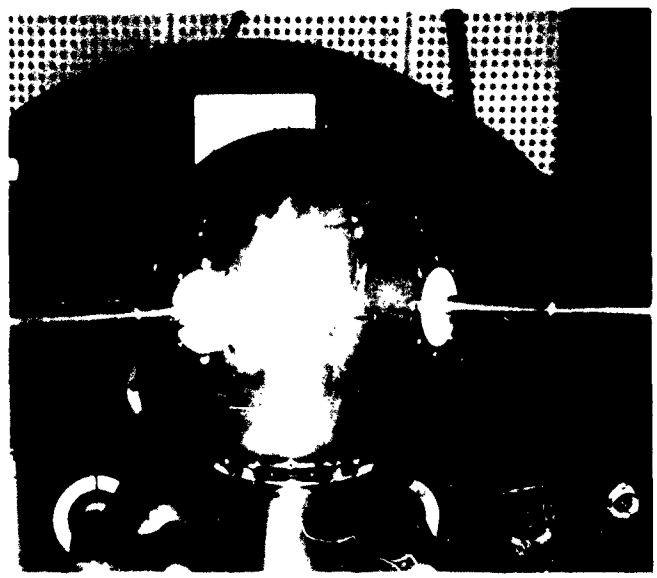

Fig. 1 - 6.44-inch magnesium satellite model after failure near separation attachment

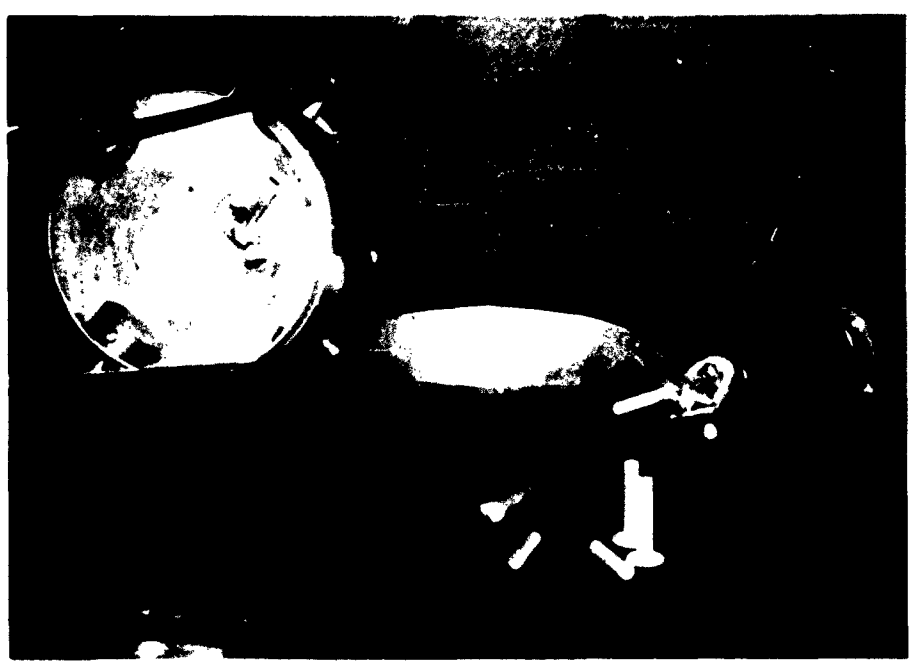

Fig. 2 - Partially disassembled 6.44-inch magnesium satellite after Kel-F parts failed

4. One antenna failed after about 5 minutes of vibration at a resonant frequency of 52 cps and 25 g, and after approximately 2-1/2 minutes at a resonant frequency of 12 cps and 5.5 g; Fig. 3 shows a node and an antinode in the antenna under the former conditions, and Fig. 4 shows the deflection of about 15 inches at the end of the antenna under the latter conditions.

Acceleration:

One antenna failed at approximately 65 g (Fig. 5). Close inspection revealed that the antenna was slightly defective at the point of failure (the first joint) prior to the test; bending occurred when the antenna came into contact with the wall of the pit which houses the centrifuge.

Separation Mechanism

Two satellite separation mechanisms have been received from the Raymond Engineering Laboratories and are now undergoing acceptance tests. The weight of the mechanism has been reduced from 1.25 lb to 0.94 lb and attempts are being made to reduce it further.

The operation of the separation mechanism (Fig. 6) may be described as follows: When a steady acceleration of 12 g or more is exerted along the axis for over 0.5 second, the "g-weight" will be displaced sufficiently to arm the unit. Shorter times will allow the weight to move, but it will reset to zero when the g-load is removed. The third stage of the launching vehicle will provide the necessary g-load to arm the mechanism, but the first and second stages cannot. If the acceleration is subsequently reduced below 1. g, the timer will start to function. After approximately 20 seconds the timer arm closes two independent electrical circuits which fire two explosive caterpillar motors. These motors expand approximately 1 inch, rotating the ejection-spring release and simultaneously pulling the locking pins so that the satellite is free from the third stage. The compressed spring expands, imparting a differential velocity of about 3 fps to the satellite and third stage.

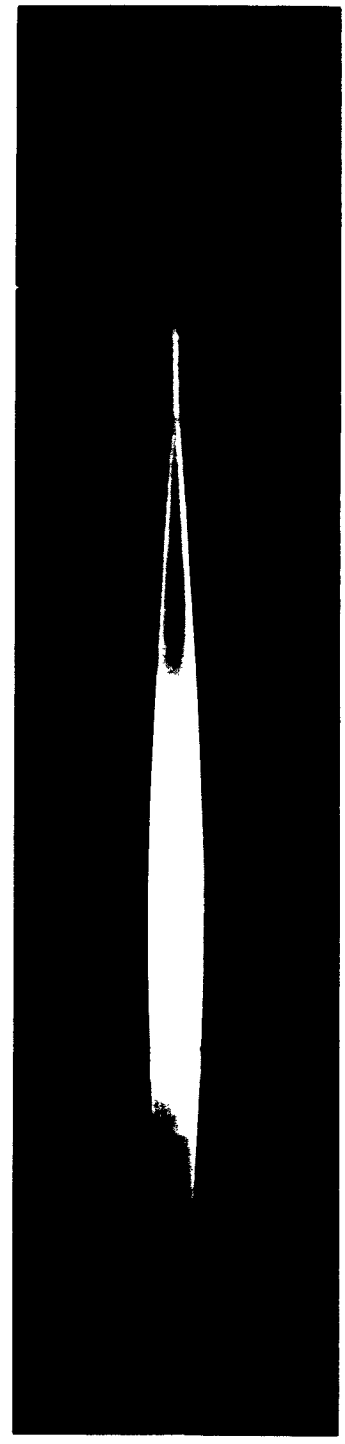

Fig 3 - Satellite antenna under resonant vibration at 52 cps and 25 g ——→

Heat Switch

The two types of heat switches for the 6.44-inch satellite* have been evaluated experimentally and the results are tabulated below:

NRL Type

1. $\frac{\text{conduction closed}}{\text{conduction open}} = 210$
2. conduction closed $\approx$ 8 mw/°C

Fenwall Type

1. $\frac{\text{conduction closed}}{\text{conduction open}} = 4$
2. conduction closed $\approx$ 0.8 mw/°C

These results indicate that the NRL design is far superior to the Fenwall design. The Fenwall Company is being given the opportunity to improve its design.

Dynamic Balancing

A portion of the equipment for dynamically balancing the satellite** is shown in Fig. 7. As a result of preliminary test runs with this device, it is believed that the specified balance limit of 2 ounces-inches can be met, and that a maximum of 0.2 lb additional weight will be required to attain this degree of dynamic balance.

ENVIRONMENTAL TESTS

Thermal tests of the 20-inch satellites are now underway to determine whether or not heat switches will be required; it is believed at present that they will not be required.

Environmental tests are being conducted on the new Lyman-alpha instrumentation layout, but these tests cannot be completed until representative telemetering circuits are available.

The two-output solar cell† has been completed and is now under test. It has been found that the output voltage variation could be reduced to between 2 and 5 percent by using a load resistance of 5 ohms or less. However, while response-vs-temperature curves were obtained over the range from room temperature to about 170°C, it was found that the cell was structurally unsuited for operation at temperatures above 150°C. A design for a cell structure to withstand temperatures up to 400°C is in the preliminary stages of development.

The output voltage of a solar cell across a 3.3-ohm load has been measured versus intensity of illumination from both a tungsten and a carbon-arc source over a range of approximately 0.1 to 60 mw/cm^2. The results indicate that meaningful data can be obtained only by using the sun as a source.

Environmental tests of the proposed satellite erosion gauges already on hand are now in progress.

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*P.V.R. No. 10, p. 16

**P.V.R. No. 10, p. 12

†P.V.R. No. 10, p. 17

Heat Switch

The two types of heat switches for the 6.44-inch satellite* have been evaluated experimentally and the results are tabulated below:

NRL Type

1. $\frac{\text{conduction closed}}{\text{conduction open}} \approx 210$
2. conduction closed $\approx$ 8 mw/°C

Fenwall Type

1. $\frac{\text{conduction closed}}{\text{conduction open}} \approx 4$
2. conduction closed $\approx$ 0.8 mw/°C

These results indicate that the NRL design is far superior to the Fenwall design. The Fenwall Company is being given the opportunity to improve its design.

Dynamic Balancing

A portion of the equipment for dynamically balancing the satellite** is shown in Fig. 7. As a result of preliminary test runs with this device, it is believed that the specified balance limit of 2 ounces-inches can be met, and that a maximum of 0.2 lb additional weight will be required to attain this degree of dynamic balance.

ENVIRONMENTAL TESTS

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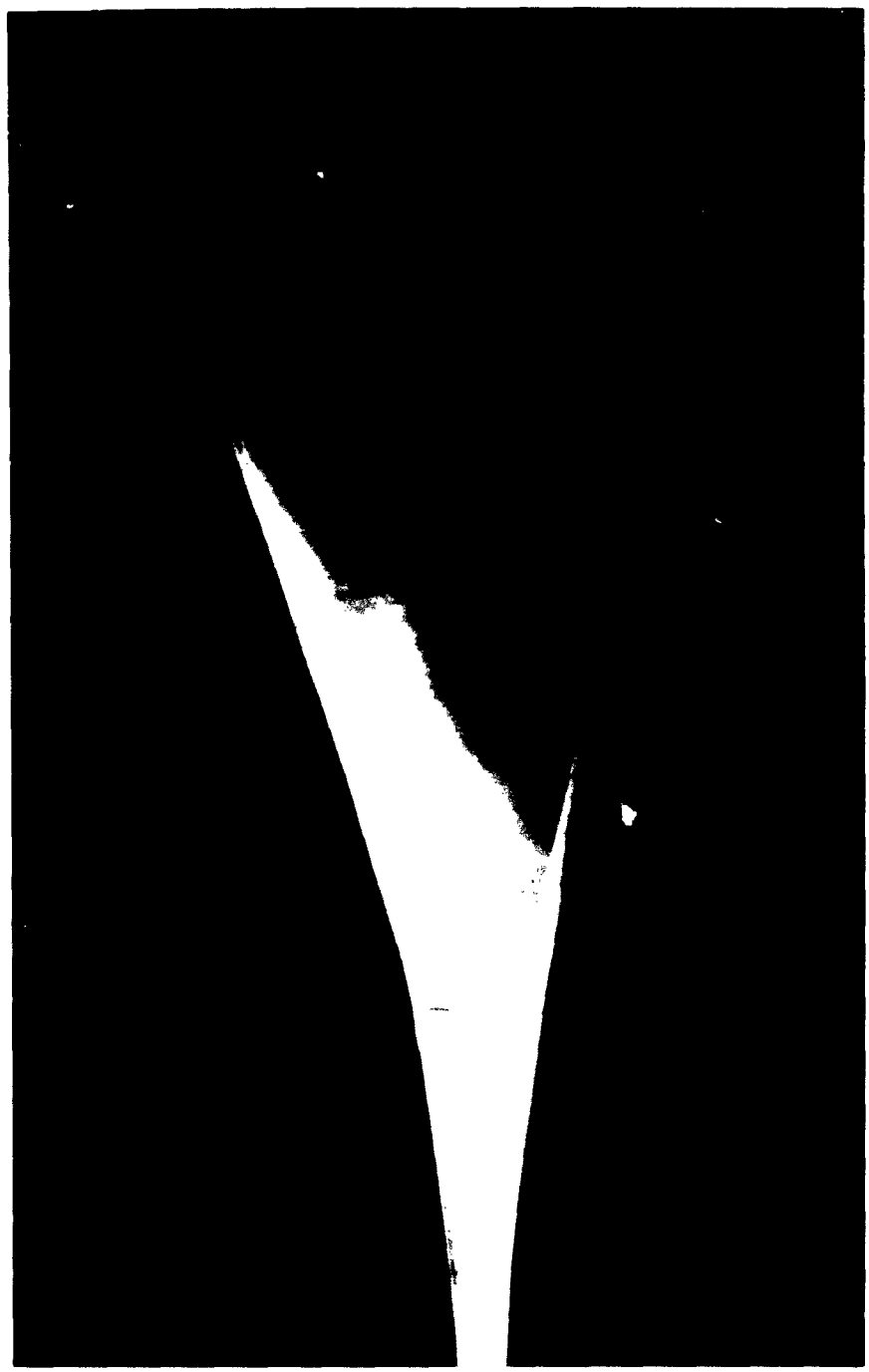


Fig. 4 - Satellite antenna under resonant vibration at 12 cps and 5.5 g

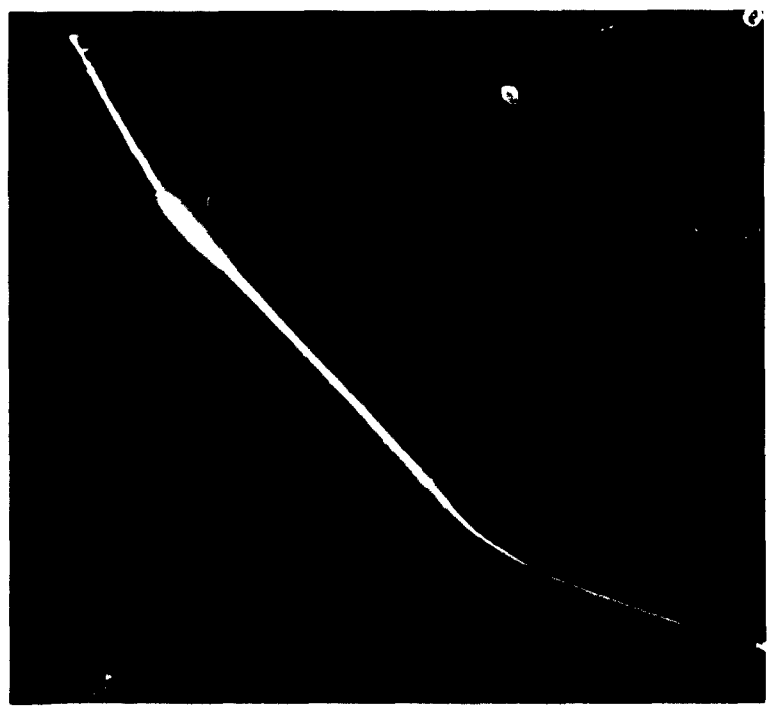
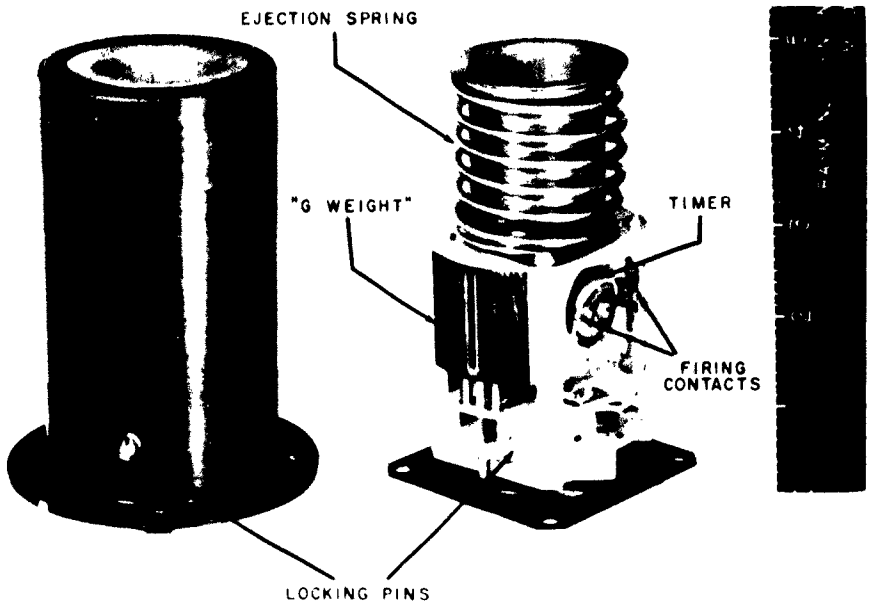
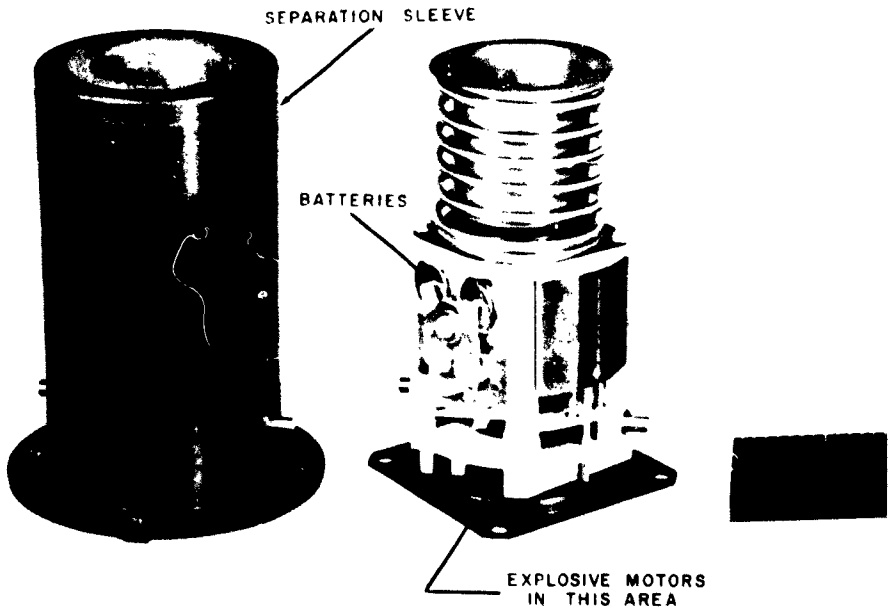


Fig. 5 - Satellite antenna after failure at acceleration of 65 g



(a) Front view



(b) Rear view

Fig. 6 - Satellite separation mechanism
(Raymond Engineering Laboratories photo)

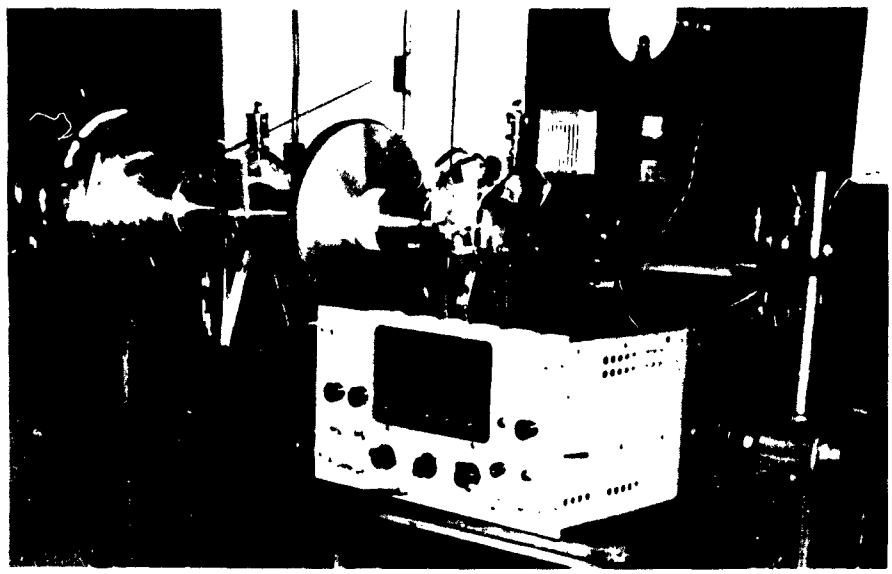


Fig. 7 - Portion of equipment for dynamically balancing the satellites

INSTRUMENTATION

A thorough analysis has been made of the telemetry requirements for the scientific experiments to be included in the NRL satellites, and an adequate channel allocation plan has been formulated. Environmental experiments concern quantities which may change significantly over a succession of orbits but whose variations during a particular telemetering record will be negligible. On the other hand, solar aspect and Lyman-alpha data will vary as a function of time during one telemetering record. Adequate detail in the Lyman-alpha experiment will be provided by the use of a 48-channel telemetry coding system with 12 channels devoted to instantaneous Lyman-alpha data (6 channels each to the solar Lyman-alpha and solar aspect cells). This provides relatively long "views" in each channel with sufficient time resolution to permit detailed studies of the values for approximately two thirds of the telemetering time. The experimenters have been provided specifications for input devices, and parallel resistances have been calculated to control the limiting values of display time for each channel in the cases of both normal operation and input device failure.

The layout of printed-circuit panels for the 48-channel system, based on the new dimensions of the satellite internal package, is underway. Transistors have been received for the early production sample units, and after the initial tests these transistors will be aged to improve their reliability.

The speed of the magnetic tape for ground recording of the telemetry signals has been reduced from 60 to 30 inches per second; this will permit recording for up to 16 minutes. In addition, five direct and two pulse-width channels will be provided in the recorder instead of the previously contemplated four and three respectively. Oscilloscope monitor

requirements have been determined and the necessary procurement arranged. The linear detector (signal converter) for the ground-station receiver has been modified to provide an output centered at 25 Kc (formerly 50 Kc) to conform to the 2:1 reduction in the tape speed. The prototype unit is now ready for delivery to the manufacturer.

A 108-Mc modulated signal source has been designed and constructed for making overall checks of the telemetry receiving system. This device will be reproduced at NRL.

A simple printed-circuit amplifier for the meteor collision detector has been completed and satisfactorily tested, and is now being adapted to the new internal package design. The amplifier and the counter will be incorporated in a single compartment.

THEORY AND ANALYSIS

The Naval Research Laboratory has been asked to specify the numerical method to be used by RCA-AFMTC in smoothing and computing velocity and acceleration from positional tracking data. This problem has been formulated and calculations are being made on the NORC computer, NPG Dahlgren, Va.

It has been established on the basis of conferences with personnel of AFMTC and ABMA, that there is a need for pyrotechnic flares to be ejected from the vehicle as a calibration point for DOVAP and a check for other tracking systems. An investigation was carried out during this period to ascertain the number of flares to be carried, when they should be ejected, vehicle mounting requirements, etc.

Investigations have been conducted to determine the constraints on the satellite launching time which are imposed by the various programs of Project Vanguard. Criteria posed by the needs of the optical program were determined and the corresponding launching intervals were calculated. Viewing criteria determined by the Lyman-alpha experiment also impose constraints upon the acceptable satellite launching times. The theory of these criteria was worked out and used to calculate the launching intervals which are acceptable from this point of view. The theory of eclipses of a close earth satallite was developed. It was applied to determine the portion of time per orbit during which the satellite is illuminated by the sun under certain conditions which could occur in the Vanguard satellite program.

ELECTRONIC INSTRUMENTATION

TELEMETERING

PPM/AM Systems

Most of the ppm/am equipment has now arrived at AFMTC, and closed-loop tests and calibrations are underway to ready this equipment for the TV-0 launching. Special precautions are being taken with the antenna mounts to prevent degradation of their performance due to climatic conditions. The ppm/am ground station has recorded transmissions radiated from hangar C.

PWM/FM Systems

The pwm/fm equipment at AFMTC is reported to be in satisfactory condition to receive one link of pwm/fm telemetering from the vehicle. Preparations are underway to make it a two-link system, as is required for future vehicles. Signals radiated from hangar C have been recorded by the pwm/fm ground station.

FM/FM Systems

The spare fm/fm vehicle telemetering transmitter for TV-1 has been checked out electrically and delivered to GLM, and the spare unit for TV-2 is presently being readied for delivery. A transitorized power supply has been designed which may replace the vibrator type now used in the fm/fm transmitters.

VEHICLE TRACKING

Electrical bench tests have begun on the AN/DPN-48 (XE-1) S-band radar beacons at Melpar; some difficulties were encountered in the modulator and the noise firing rate was excessive. Further work will be done on the beacons to overcome these difficulties. Melpar has failed to meet the contractual delivery date of 20 October for the first of these units.

The Bomac BL-212 C-band magnetron is in short supply because of technical difficulties encountered in production. One magnetron in working condition has been made available to Project Vanguard by the Army Signal Corps for use in the AN/DPN-31 C-band beacon. Since this tube is used in both the DPN-31 and the DPN-48 (XE-1) C-band beacons, the shortage may seriously affect the delivery of these beacons.

There is some uncertainty concerning the availability of C-band Mod III radars at AFMTC for the scheduled firing date of TV-1. Because of this fact the AN/DPN-31 C-band beacon scheduled for use in TV-1 will not be used in this vehicle, but will be used in TV-2. With the exception of this beacon, all range safety and tracking equipment for TV-2 has been delivered to GLM on or before the scheduled dates.

Requests have been issued for bids on production of the transistorized decoder developed by Project Vanguard to replace the KY-55/ARW decoder not used with the AN/ARW-59 range safety command receiver.

THE MINITRACK SYSTEM

Vibration tests on 100-mw transistor oscillators with Western Electric GA 53233 transistors are continuing. These units utilize components identical to those being used for the satellite transmitter, but are made for operation in TV-0. They are potted in foam plastic in a manner identical to that of the satellite transmitters. Tests on a centrifuge at 50 g continuously for 5 minutes, and on a vibration machine with sinusoidal drive up to 28 g at 2000 cps, have been carried out on a prototype unit. Except for a momentary frequency-shift transient of unknown origin during the vibration test, no abnormal effects were noted during or after these tests.

Temperature tests over a range of 30° to 100°C for one two-hour cycle, and continued operation at 50°C for a period of two weeks have been completed on a 100-mw unit. The results of these tests showed no serious variations of output power or frequency as a result of changes in temperature or supply voltage.* Similar tests up to 70°C on the 10-mw satellite transmitter with Philco SBDT-12 transistors show the temperature coefficient of frequency to be about one part per million per degree C, and the power output at 70°C to be within 3 db of the value at 0°C. The overall efficiency of these units at 30°C is 20 percent.

Modulated transmitter developments are continuing, with primary emphasis on a unit to provide about 50 mw output power at 100 percent amplitude modulation for continuous telemetering. This unit, utilizing one Western Electric transistor as the crystal-controlled 108-Mc oscillator and a second Western Electric transistor as a modulated power amplifier stage, is nearing the environmental evaluation stage.

Four Fruehauf trailers have been delivered to the Bendix Radio Division as government furnished equipment on the Minitrack ground station unit contract. An amendment to this contract has been signed requiring Bendix to provide ten telemetry receiver racks to be delivered simultaneously with the Minitrack ground station units, excepting units 1 and 2.

The submission of bids by six invited participants for the production of 74 Minitrack antenna arrays for use at the station sites is to be closed at noon on 16 November. These bids are based on the D. S. Kennedy design selected on the basis of prototype units submitted by that company and by the Technical Appliance Corporation last spring and evaluated comparatively at the Blossom Point Minitrack Test Facility during the last three months.

The new time-standard and phase-measurement racks for the prototype Minitrack station at Blossom Point will be installed during the week of 19 November. New developments at this station include the filling of the ditches preparatory to grading and seeding, and the installation of a 20-Mc Yagi antenna for the reception of WWV without fading at all times, day or night.

A 15-Mc Yagi antenna has been installed at NRL for the reception of WWVH, the Bureau of Standards time station in Hawaii, to check the long distance setting of the precision time standard. Preliminary tests indicate that 1-millisecond timing accuracies can be maintained over these distances by using visual measurement of the comparison oscilloscope presentation of the received signal and the locally generated time signals. The

*These tests were performed using WE-53233 transistors that had been selected on the basis of "cold" vibration tests. Of 12 production-line transistors, only 8 survived the "cold" tests; of 9 laboratory-produced transistors, 9 survived the "cold" tests.

use of recording camera techniques should simplify this procedure and eliminate any reading error.

The first prototype Mark II Minitrack system is now at the Cape Canaveral Auxiliary Air Force Base of AFMTC for operations in connection with TV-0, using one pair of antennas on a 500-foot north-south baseline. A second unit of this type is being completed for use at Blossom Point. Prior to its shipment to Cape Canaveral, the use of the prototype unit at Blossom Point against the radio stars in Cygnus and Cassiopea and the sun provided signals of such strength that the use of these stars is being considered for calibration of the Mark II system where the accurate location of the station meridian is the primary concern. An extended-bandwidth receiver is being studied for application to this system to increase its sensitivity by about 10 db when tracking radio stars.

Because of technical considerations, the utility of Minitrack Station No. 4 at Rio Hato, Panama has been reconsidered. Establishment of the San Diego Station provided nearly total coverage of all orbits that would intercept Rio Hato from the northwest in the orbital inclination range of 35 to 40 degrees and the Antigua station provided a similar coverage for all orbits that would intercept Rio Hato from the southwest. These cases are shown in Fig. 8 for a 35-degree orbital inclination and Fig. 9 for a 40-degree orbital inclination. For these reasons, the Rio Hato station has been eliminated from the Minitrack complex. This station will probably be offered to Australia for establishment and operation by that country on a no-charge basis at Woomera in cooperation with the British Government.

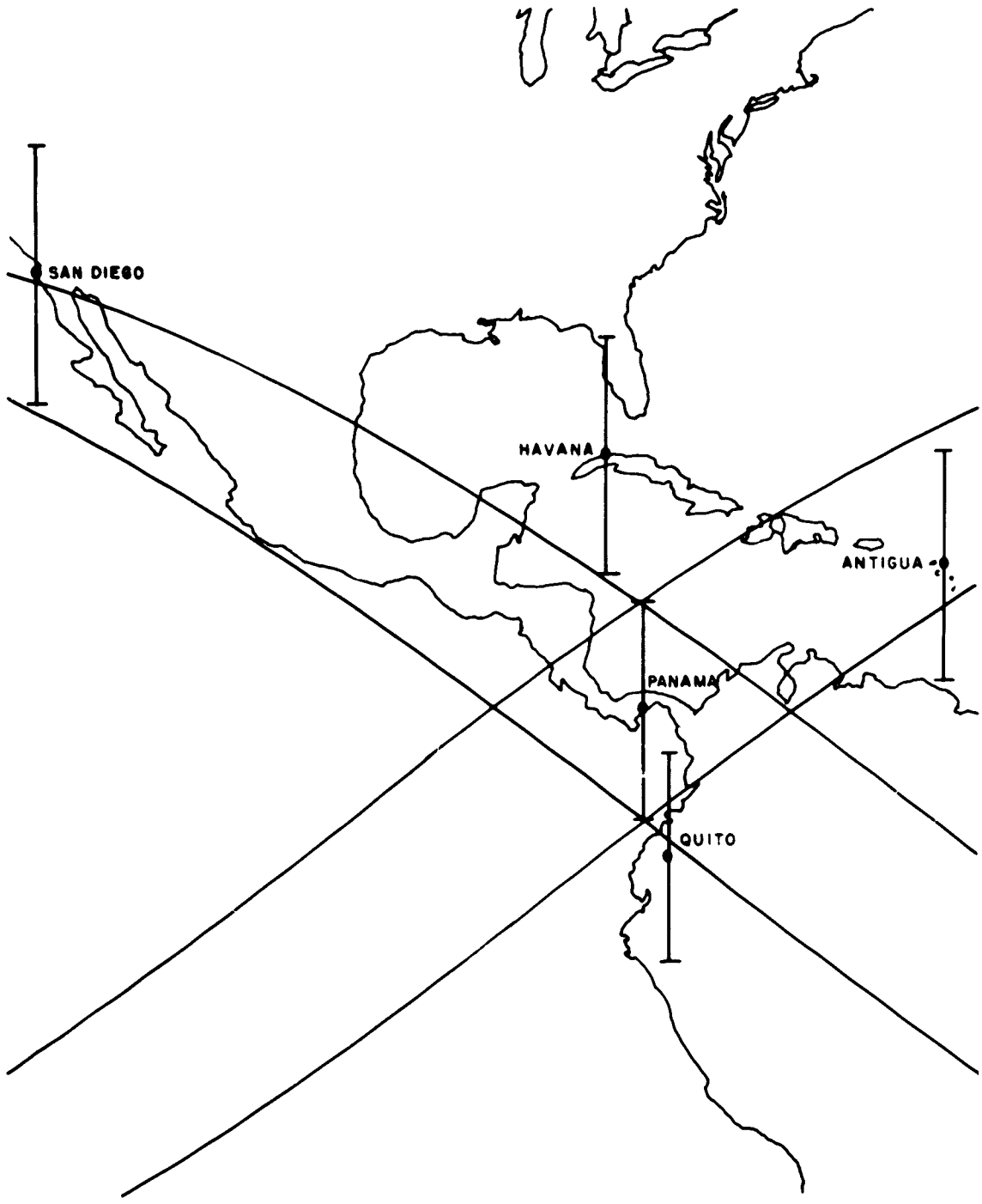


Fig. 8 - Map showing interception of 35-degree Rio Hato orbits by Antigua and San Diego stations

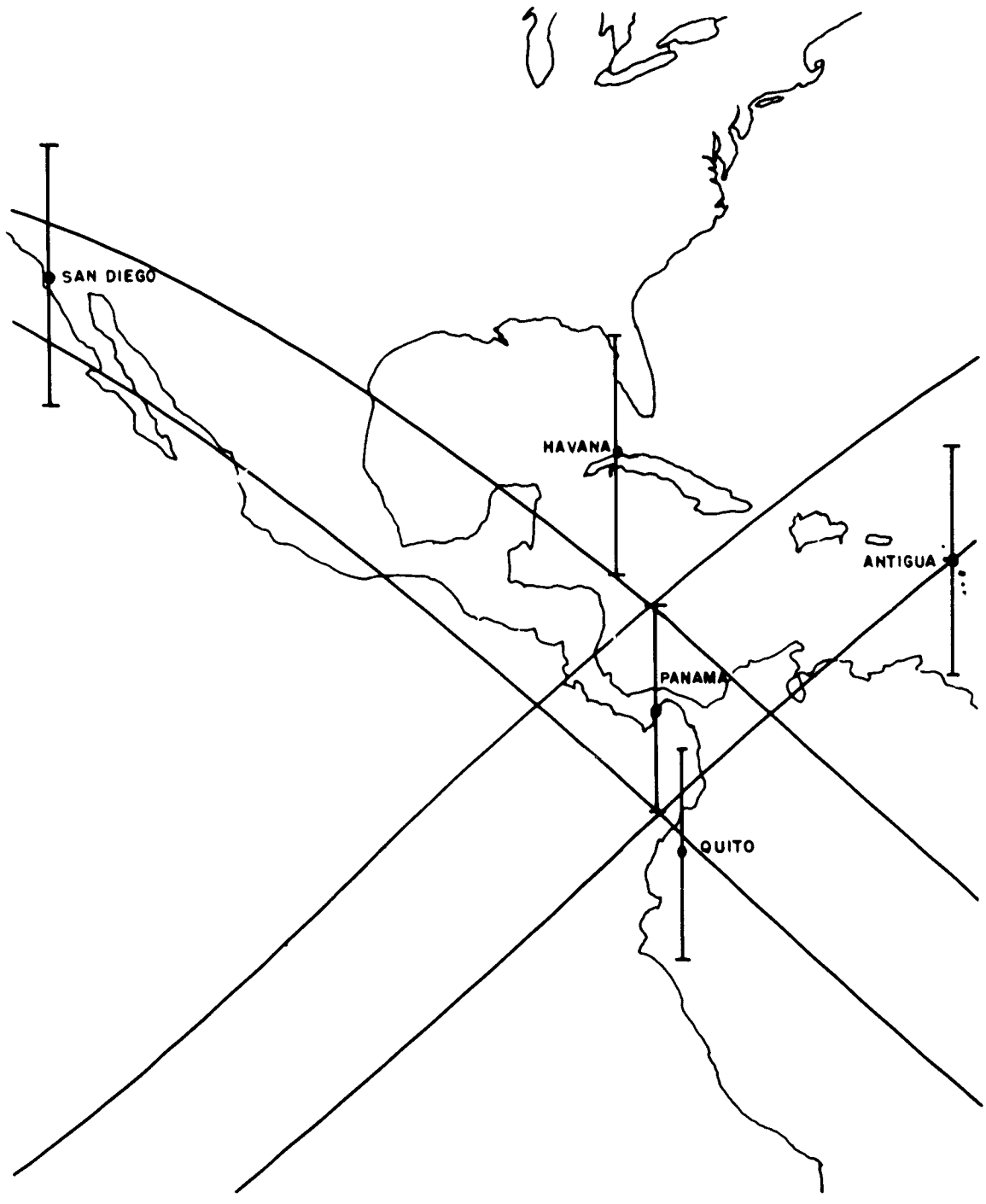


Fig. 9 - Map showing interception of 40-degree Rio Hato orbits by Antigua and San Diego stations

DATA PROCESSING

TELEMETERED DATA

The automatic recording and reduction facility (ARRF) for telemetered data being procured from Radiation, Inc. is shown in Fig. 10 in the form of a simplified block diagram. Those parts of the system which must be developed are shaded; the other parts are already developed or need only slight modification. The digital data recording portion of the facility, shown in the solid blocks on the left side of the figure, will be mounted in a trailer located on the NRL telemetry pad at Cape Canaveral. The digital data reduction portion of the facility will be located first at the manufacturer's plant and later in hangar space at Cape Canaveral.

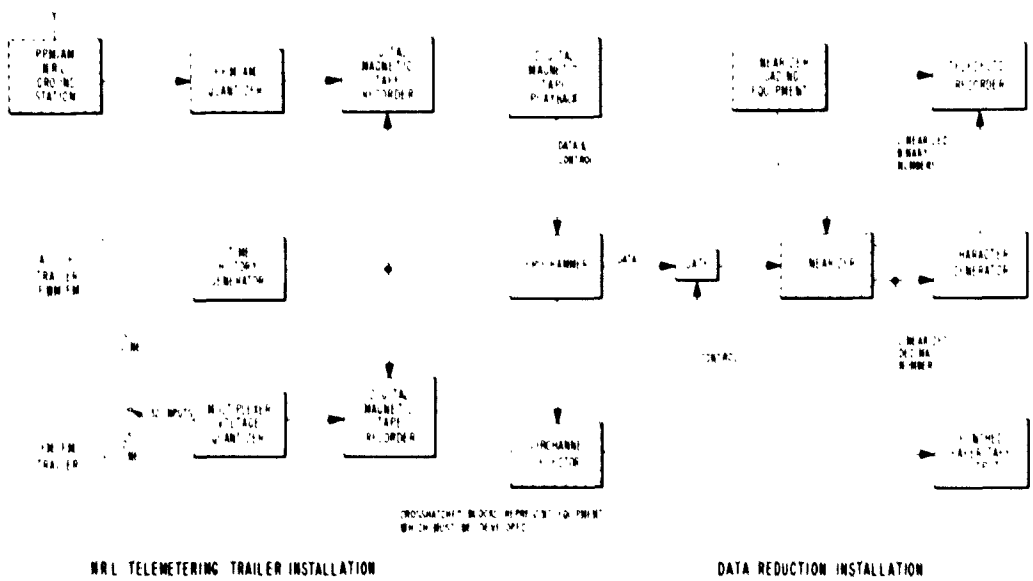


Fig. 10 - Automatic recording and reduction facility for telemetered data

The ARRF trailer (the data recording system) will contain two separate subsystems, one for conversion to digital code of ppm/am data and one for conversion of pwm/fm, or of fm/fm data. For the ppm/am data, a modified NRL ground station monitor rack will receive signals directly from the telemetering antenna and convert them to suitable form for the ppm/am quantizer. The quantizer will consist of gates, an oscillator, and a counter suitably arranged to measure and encode the positions of the telemetered pulses. The binary codes thus obtained will be recorded on a magnetic tape recorder. Timing information and subcommutator synchronization signals are also recorded.

In the case of fm/fm and pwm/fm equipment, voltages representing separate telemetered channels will be sent to the ARRF recording trailer from the other telemetering trailers. Ten such lines, representing ten channels, will be brought in from the pwm/fm trailer and recorded in real time. The ARRF equipment has 32 independent inputs, so that some lines may be sampled at an increased rate if desired. It is planned to play back the fm/fm video tape recording after the flight to produce a digital magnetic tape record. The input signals, which will be multiplexed and converted to binary code, will be recorded on magnetic tape along with timing information.

All tapes will be played into the tape-playback equipment in the data reduction system (shown on the right side of Fig. 10). The programmer can be set to select the desired channel from the digital tape, and start and stop the readout process at preselected points of the record. In addition, a subchannel selector will be provided to isolate subchannel information in the ppm/am record. The digital codes passed by the programmer and subchannel selector will be transmitted to the linearizer, which is essentially a digital function table arranged to eliminate nonlinearities in the input data, producing corrected binary codes which are plotted in analog form on the Teledeltos recorder. The linearizer will also produce four-decimal-digit words representing end-organ values, which are in turn fed to a character generator and printed at intervals along with the analog plot of the linearized binary data on the Teledeltos record. The decimal information can also be punched on paper tape at a rate, referred to real time, of approximately 4 samples per second for further analysis in a digital computer.

An NRL ground station monitor rack has been modified at NRL and will be sent to Radiation, Inc. as soon as it is needed there. In the meantime, its operation is being thoroughly checked and calibration procedures are being tested. The subchannel selector is in final phase of development at NRL. The linearizer and character generator will be procured by Radiation, Inc. from other companies. The ppm/am quantizer is to be developed by Radiation, Inc. The remaining parts of the system will utilize standard or slightly modified Radiation, Inc. equipment.

ORBITAL DATA

The architect for the International Business Machines Corporation is continuing with the remodeling drawings for the Vanguard computing center at 615 Pennsylvania Avenue, N. W., Washington, D. C.

Improved versions of the Fourier series addition and multiplication subroutines have been completed. Subroutines for partial differentiation of Fourier series have been programmed and are now being checked. A test calculation has been run with the three-observation elliptic orbit subroutines, and the programming of similar subroutines for four observations has been undertaken.

THIRD-STAGE FIRING PREDICTION

In connection with the ground-controlled third-stage firing system, the RCA Service Company at AFMTC is continuing the detailed specifications for the digital data transmission equipment required for the information link between the radars AN/FPS-16 (at Grand Bahama Island and at Patrick Air Force Base) and the IBM 704 computer (at Cape Canaveral). Contracts for this equipment should be let shortly since the installation is expected to be in operation for TV-3 and subsequent vehicles.

* * *

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